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E1F FKG FLM

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(54) Abstract Title

**Electrically controlling multiple downhole devices**

(57) A production well control system 10 for electrically controlling multiple downhole devices (41, figure 2) individually or as a group comprises a surface control unit 12, a downhole control module 30 and multiple interface units 40, 50 etc. The operator inputs a command or request to the surface control unit which is passed to a power and communication system 14. The power and communication system generates a command signal of sufficiently high voltage to be sent downhole to the control module 30 which interprets and reformats the signal. The control module is connected to the multiple interface units, each of which is associated with a valve 41. Each interface unit is programmed to respond to a certain signal, energising its particular valve and transmitting data back to the control module 30. Alternatively, the valves are automatically actuated by the sensing of a downhole parameter such as temperature or pressure.

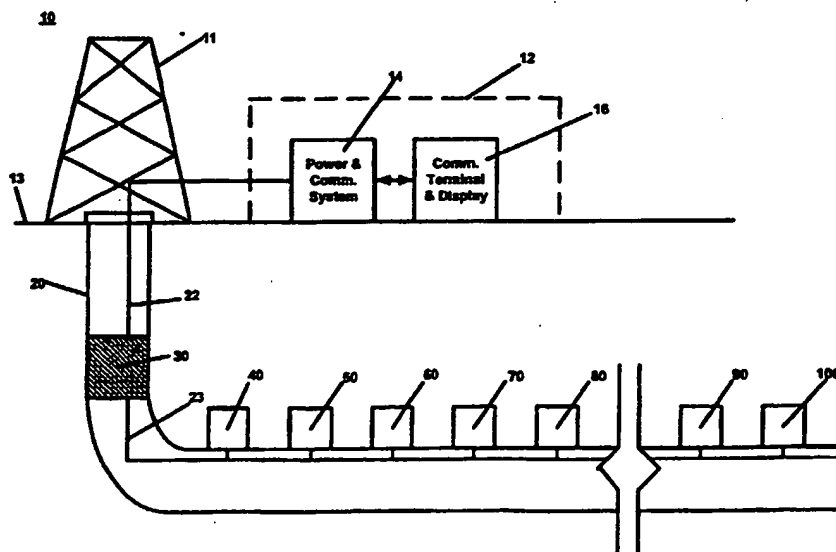


Figure 1

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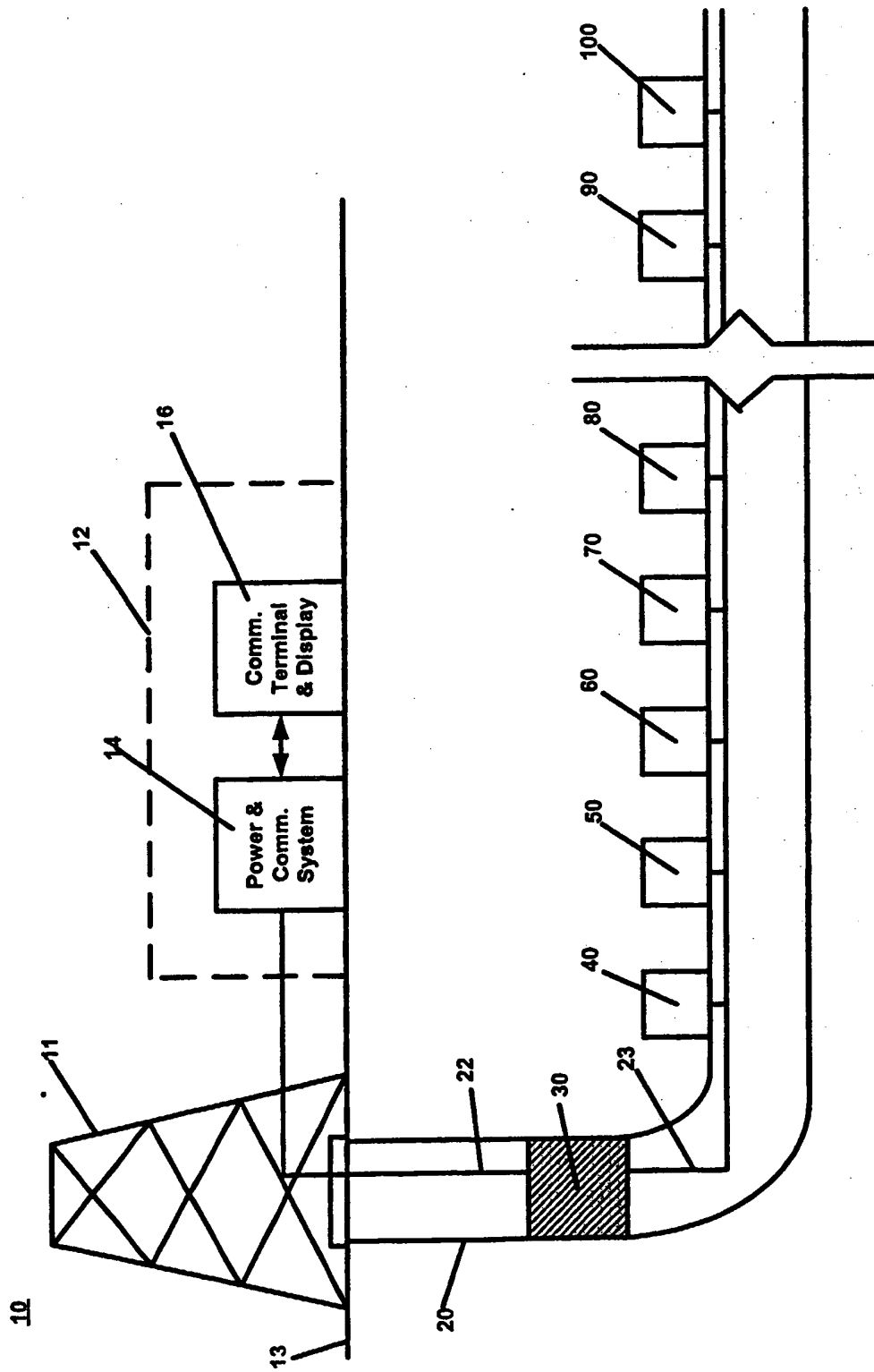


Figure 1

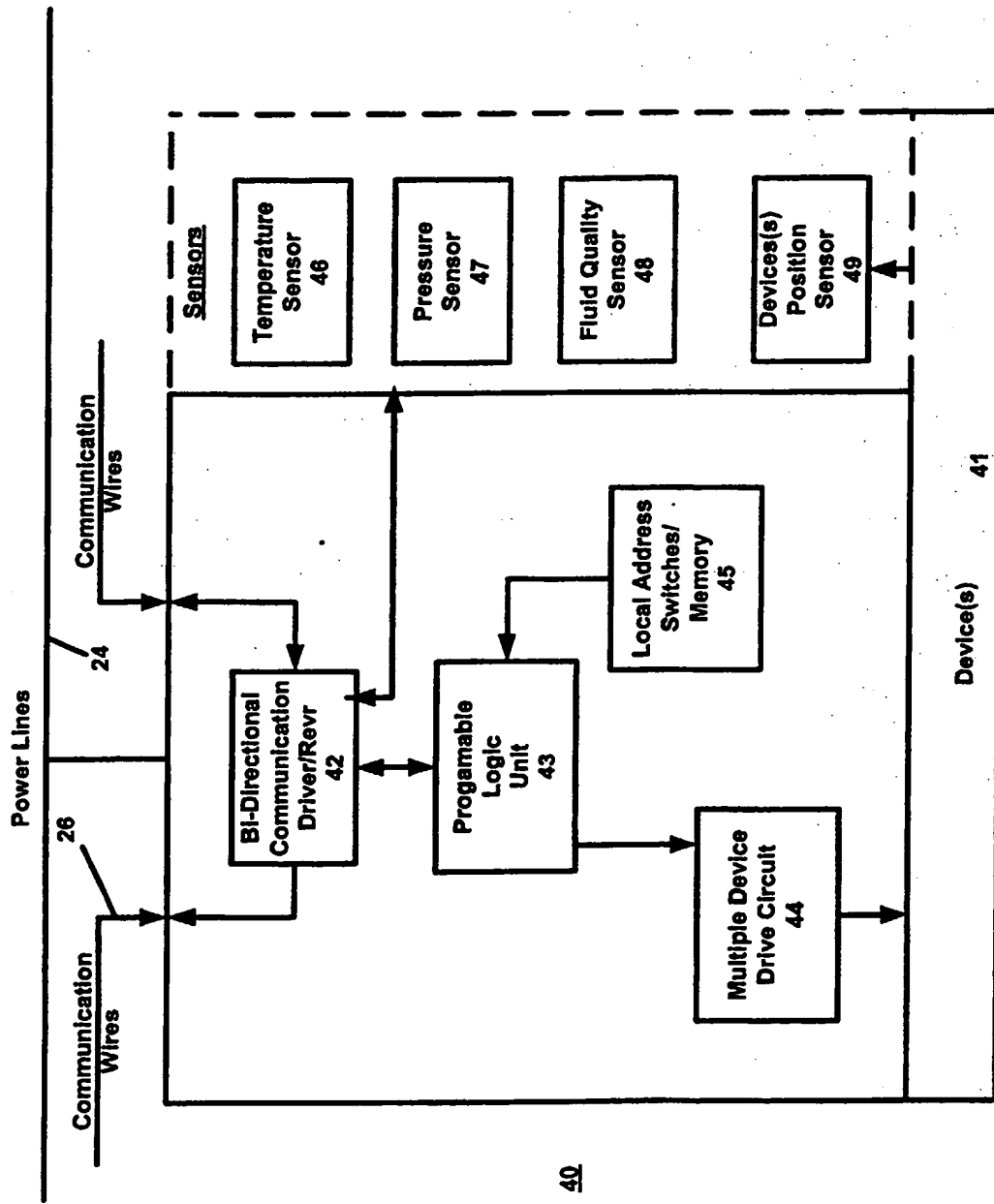


Figure 2

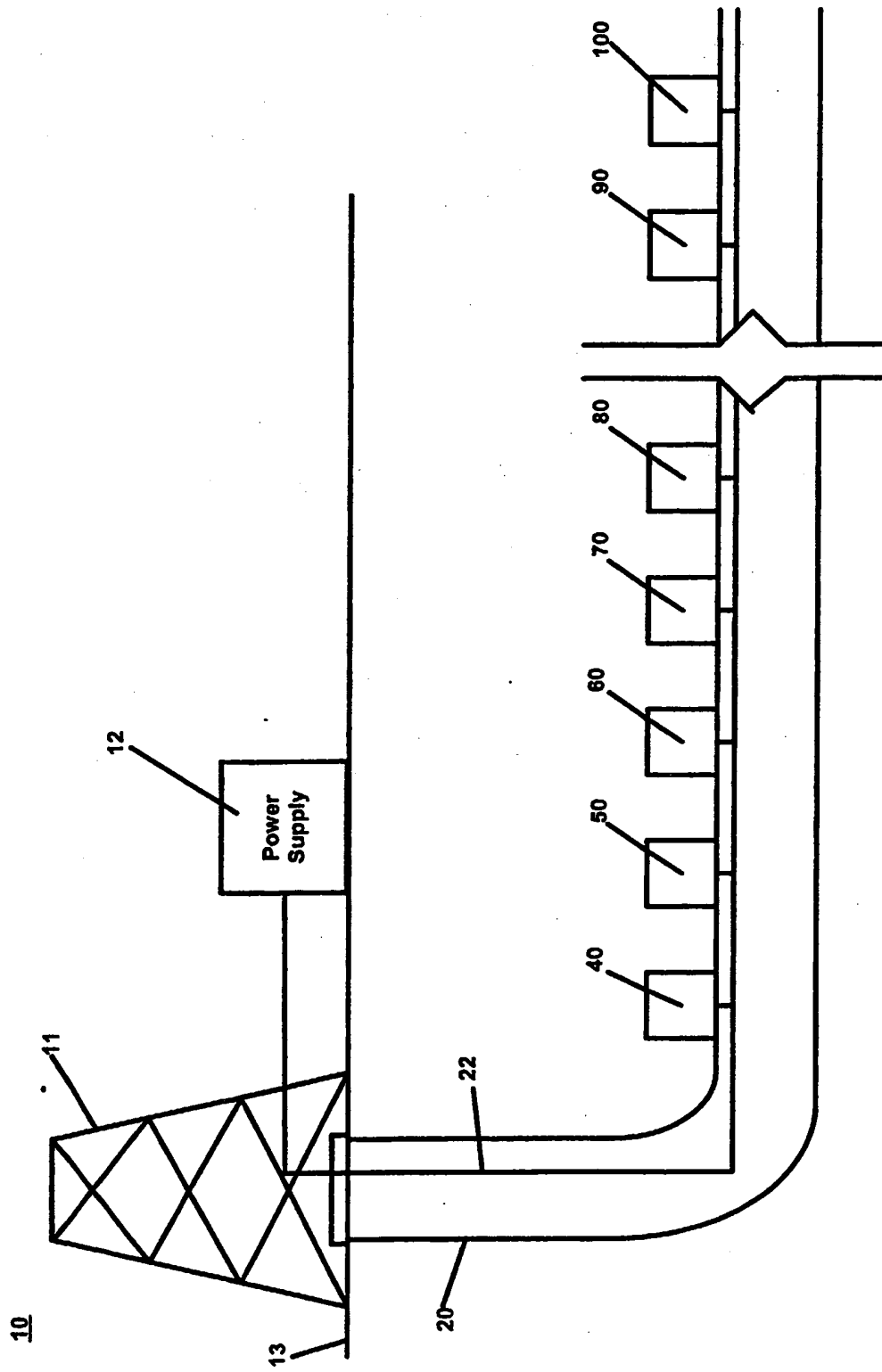
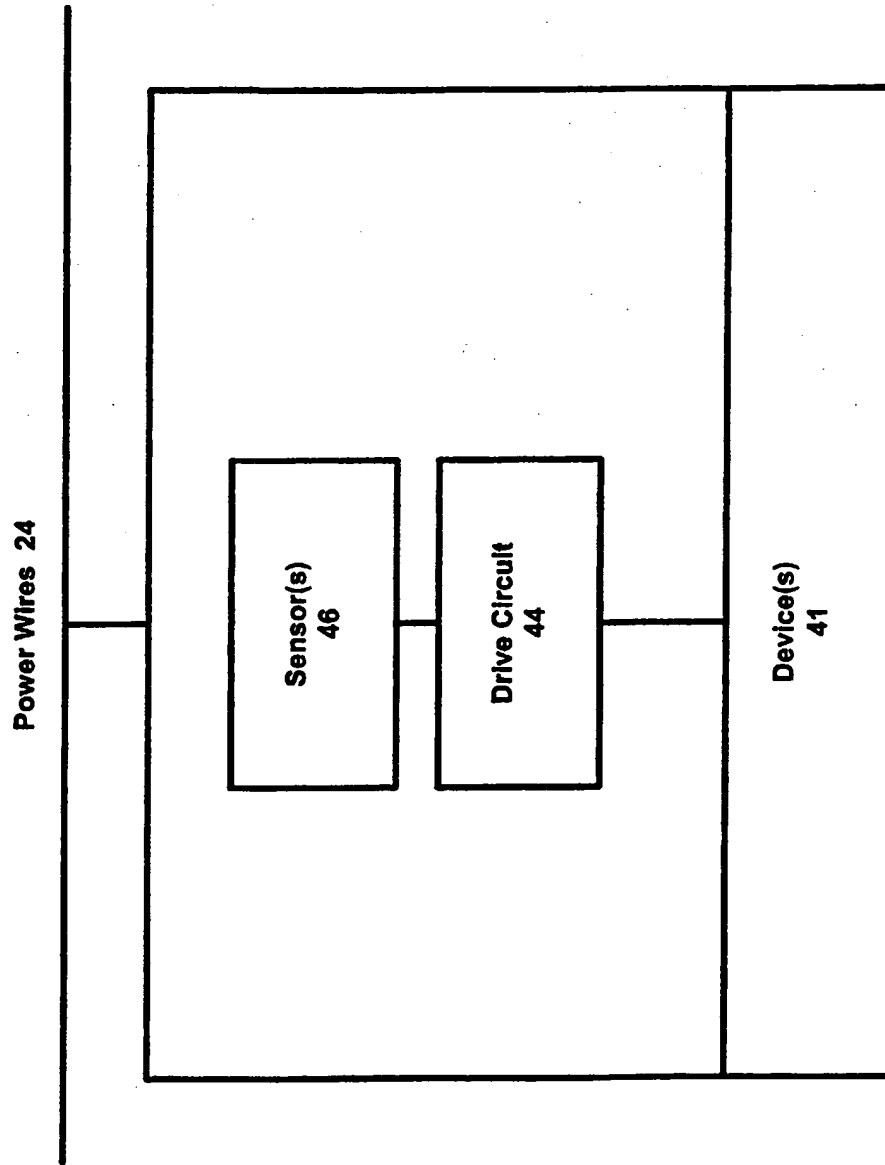


Figure 3



40

Figure 4

1 APPARATUS AND METHOD FOR ELECTRICALLY CONTROLLING  
2 MULTIPLE DOWNHOLE DEVICES

3  
4 BACKGROUND OF THE INVENTION

5  
6 Field of the Invention

7 This invention relates generally to oilfield well  
8 operations and more particularly to an apparatus and  
9 method for electrically controlling multiple  
10 downhole devices.

11  
12 Description of the Related Art

13 The control of oil and gas production wells  
14 constitutes an on-going concern of the petroleum  
15 industry due, in part, to the enormous monetary  
16 expense involved as well as the risks associated  
17 with environmental and safety issues.

18  
19 It will be appreciated that relatively simple, timed  
20 intermittent operation of valves and the like are  
21 often not adequate to control either outflow from  
22 the well or injection to the well so as to optimize  
23 well production. As a consequence, sophisticated  
24 computerized controllers have been positioned at the  
25 surface of production wells for control of downhole  
26 devices such as motor valves.

27  
28 Surface controllers are often hardwired to downhole  
29 sensors which transmit information to the surface  
30 such as pressure, temperature and flow. This data  
31 is then processed at the surface by the computerized  
32 control system.

1  
2 While it is well recognized that petroleum  
3 production wells will have increased production  
4 efficiencies and lower operating costs if surface  
5 computer based controllers and downhole  
6 microprocessor controllers (actuated by external or  
7 surface signals) are utilized, current control  
8 systems nevertheless suffer from drawbacks and  
9 disadvantages. For example, reliability of surface  
10 to downhole signal integrity in a surface control  
11 system wherein a downhole microprocessor is actuated  
12 by a surface signal is a major concern. It will be  
13 appreciated that should the surface signal be in any  
14 way compromised on its way downhole, then important  
15 operations will not take place as needed.  
16  
17 Prior art surface control systems generally require  
18 a surface platform at each well for supporting the  
19 control electronics and associated equipment.  
20 However, in many instances, the well operator would  
21 rather forego building and maintaining a costly  
22 platform. Thus, a problem is encountered in that  
23 use of present surface controllers require the  
24 presence of a location for the control system,  
25 namely the platform.  
26  
27 Disadvantages of present production well control  
28 systems involves the extremely high cost associated  
29 with implementing changes in well control and  
30 related workover operations. Presently, if a  
31 problem is detected at the well, the customer is  
32 required to send a rig to the wellsite at an

1 extremely high cost (e.g., 5 million dollars for 30  
2 days offshore work). The well must then be shut in  
3 during the workover causing a large loss in revenues  
4 (e.g., 1.5 million dollars for a 30 day period).  
5 Associated with these high costs are the relatively  
6 high risks of adverse environmental impact due to  
7 spills and other accidents as well as potential  
8 liability of personnel at the rig site. Of course,  
9 these risks can lead to even further costs. Because  
10 of the high costs and risks involved, in general, a  
11 customer may delay important and necessary workover  
12 of a single well until other wells in that area  
13 encounter problems. This delay may cause the  
14 production of the well to decrease or be shut in  
15 until the rig is brought in.

16

#### 17 SUMMARY OF THE INVENTION

18 The present invention provides a production well  
19 control system for controlling multiple downhole  
20 devices, preferably, but not limited to, valves,  
21 separated by thousands of meters. This system  
22 allows for economic, reliable and reversible means  
23 of controlling a plurality of downhole devices.

24

25 In accordance with a first embodiment of the present  
26 invention, a surface control unit, downhole control  
27 module and interface unit are provided for  
28 selectively controlling downhole devices. An  
29 important feature of this invention is the ability  
30 to access individually, or as a group, multiple  
31 devices (e.g., valves) arranged in a distributed  
32 scheme. The number of downhole devices that can be



1 controlled by this apparatus is only limited by the  
2 data address sizes, the power delivered and the  
3 power consumed. Additionally, the apparatus is  
4 inherently more reliable with each downhole device  
5 electrically coupled to an interface unit having a  
6 unique, stored address which must correspond to a  
7 surface transmitted address before actuation of the  
8 downhole device.

9  
10 In accordance with a second embodiment of the  
11 present invention, comprising downhole sensors,  
12 downhole devices and a downhole control module  
13 whereby the control module automatically controls  
14 the downhole devices based upon a sensed downhole  
15 parameter or event. Therefore, using downhole  
16 sensors, the downhole control module will monitor  
17 actual downhole parameters (e.g., pressure,  
18 temperature, flow) and automatically execute control  
19 instructions to activate the downhole devices when  
20 parameters reach a preset limit or are outside of an  
21 optimum operating range.

22  
23 In contrast to the first embodiment, well control  
24 systems which consist of a control module located  
25 wholly at the surface and a downhole computer system  
26 which requires an external initiation signal (as  
27 well as a surface control system), the downhole well  
28 production control system in the second embodiment  
29 automatically operates based on downhole conditions  
30 sensed in real time without the need for a surface  
31 or external signal. This important feature  
32 constitutes a significant advance in the field of

1 production well control. Additional advantages of  
2 this system include elimination of the need for a  
3 surface platform and an even more reliable  
4 communication system since no surface to downhole  
5 actuation signal is required and the associated risk  
6 that such an actuation signal will be compromised is  
7 therefore rendered moot.

8  
9 A power source provides energy to the downhole  
10 control unit in both embodiments described below.  
11 Power for the power source can be generated,  
12 preferably, at the surface or in the wellbore (e.g.,  
13 by a turbine generator) or supplied by energy  
14 storage devices such as batteries (or a combination  
15 of one or more power sources). The power source  
16 provides electrical voltage and current to the  
17 downhole electronics, electromechanical devices and  
18 sensors in the wellbore.

19  
20 Examples of the more important features of the  
21 invention thus have been summarized rather broadly  
22 in order that the detailed description thereof that  
23 follows may be better understood, and in order that  
24 the contributions to the art may be appreciated.  
25 There are, of course, additional features of the  
26 invention that will be described hereinafter and  
27 which will form the subject of the claims appended  
28 hereto.

29  
30 **BRIEF DESCRIPTION OF THE DRAWINGS**

31 For detailed understanding of the present invention,  
32 references should be made to the following detailed

1 description of the preferred embodiment, taken in  
2 conjunction with the accompanying drawings, in which  
3 like elements have been given like numerals and  
4 wherein:

5

6 **FIGURE 1** is a schematic diagram of a production  
7 system that employs the apparatus of the present  
8 invention;

9

10 **FIGURE 2** is a block diagram showing an interface  
11 unit in accordance with the present invention;

12

13 **FIGURE 3** is a schematic diagram of the production  
14 system that employs an alternative embodiment of the  
15 present invention; and

16

17 **FIGURE 4** is a block diagram showing a control unit  
18 of the alternative embodiment.

19

20 **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

21 **Figure 1** is a schematic diagram of a production  
22 system 10, including a conventional derrick 11. A  
23 surface control unit 12 at the surface allows an  
24 operator to generate a command/request to be  
25 executed downhole. The operator may request  
26 downhole data or actuate one or more downhole  
27 devices by inputting a command into a communication  
28 terminal and display 16. The command is  
29 communicated by wire or wireless to a power and  
30 communication system 14.

31

1 The power and communication system 14 generates a  
2 command sequence and sufficient voltage to drive the  
3 selected downhole device. Specifically, the power  
4 and communication system 14 encodes the operator's  
5 command as a command signal using a synchronized  
6 communication technique, preferably Manchester data  
7 encoding. The power and communication system 14  
8 also generates a sufficiently high voltage to ensure  
9 that the command signal and activation voltage  
10 arrive at a downhole control module 30. The command  
11 signal and activation voltage are transmitted from  
12 the power and communication system 14 to the  
13 downhole control module 30 via twisted pair wiring  
14 housed in armored and shielded lines 22 extending  
15 downward from the surface 13 into the wellbore 20.

16  
17 Upon receipt of the command signal and activation  
18 voltage, the downhole control module 30 interprets  
19 and reformats the command signal before transmitting  
20 a command serial data package and the activation  
21 voltage via armored and shielded lines 23,  
22 comprising a bi-directional four wire communication  
23 path comprising two wires for communicating power,  
24 one wire for communicating a clock pulse and one  
25 wire for communicating data. Power lines 24 and  
26 communication lines (e.g., clock pulse wire and data  
27 wire) 26, shown in Figure 2, are connected to an  
28 interface unit 40 which is electrically coupled to  
29 at least one downhole device 41, preferably, but not  
30 limited to, a valve. Returning to Figure 1, the  
31 downhole control module 30 may transmit the command  
32 signal and activation voltage to multiple interface

1 units 40, 50, 60, 70, 80, 90 and 100 in a  
2 distributed control scheme.

3  
4 As shown in Figure 2, the interface unit 40,  
5 comprises a bi-directional communication transmitter  
6 and receiver or transceiver 42 which receives and  
7 transmits the data and clock pulse from  
8 communication line 26. The receiver/transmitter or  
9 transceiver 42 allows data to travel bi-  
10 directionally through the armored and shielded wire  
11 23 in a half duplex manner. A programmable logic unit  
12 43, within the interface unit 40, decodes the  
13 address and clock and compares the transmitted  
14 address in the command serial stream to the local  
15 address stored in memory 45. The local address is  
16 either electrically programmed before or after the  
17 interface unit 40 is placed downhole or hardwired  
18 into the interface unit 40 prior to placement  
19 downhole.

20  
21 If the transmitted address in the command serial  
22 stream and the stored address in the interface unit  
23 40 are equivalent, and depending upon the operator's  
24 command/request, the downhole device drive circuit  
25 44 will be energized and the downhole device 41  
26 actuated (i.e., opens, closes, partially opens or  
27 closes) or data may be obtained from various  
28 downhole sensors including, but not limited to, a  
29 temperature sensor 46, pressure sensor 47, fluid  
30 sensor 48 and/or downhole device position sensor 49.  
31 This data is then transmitted to the downhole  
32 control module 30 and the surface control unit 12.

1  
2 If the transmitted address in the command serial  
3 stream does not correspond to the stored address in  
4 the interface unit 40, the bi-directional  
5 transceiver 42 transmits the command serial stream  
6 to the next interface unit 50 downstream. Following  
7 this transmission, the transmitter portion of the  
8 transceiver 42 is de-energized and the receiver  
9 portion is energized. This process continues until  
10 the command serial stream reaches the appropriate  
11 interface unit containing the identical address as  
12 the transmitted address in the command serial  
13 stream.

14  
15 **Figure 3** illustrates an alternative embodiment of  
16 the present invention. As in the first embodiment,  
17 the alternative embodiment includes a production  
18 system 10 comprising, in part, a conventional  
19 derrick 11. However, unlike the first embodiment,  
20 the alternative embodiment does not require  
21 transmission of surface commands since actuation of  
22 the downhole device or group of downhole devices is  
23 initiated upon the sensing of a preset downhole  
24 parameter (e.g., temperature, pressure, flow or  
25 change in position of the downhole device) or event.

26  
27 Preferably, a power supply 12 is located at the  
28 surface to generate sufficient power to drive a  
29 downhole control unit 40 and at least one downhole  
30 device 41. The power from the supply 12 is  
31 transmitted via armored and shielded lines 22  
32 extending downward from the surface 13 into the

1 wellbore 20 to the downhole control unit 40 and at  
2 least one downhole device 41. However, it is  
3 contemplated that power for the power supply can be  
4 generated in the wellbore (e.g., by a turbine  
5 generator) or supplied by energy storage devices  
6 such as batteries (or a combination of one or more  
7 power sources).

8  
9 **Figure 4** illustrates a block diagram of the downhole  
10 control unit 40, comprising a sensor device 46 and a  
11 drive circuit 44. As mentioned above, the downhole  
12 control unit 40 operates autonomously by sensing a  
13 preset downhole parameter, (i.e., temperature,  
14 pressure, flow, position or other area of interest)  
15 and actuating the downhole device 41. For example,  
16 in controlling flow through a valve which is prone  
17 to heat up or cool down due to pressure differences  
18 on either side of the valve, a silicone diode  
19 temperature switch or a bi-metal thermostat may be  
20 used as the sensing device 46. Upon sensing a  
21 preset temperature, the sensor device 46 switches  
22 from an open state to a closed state permitting  
23 power from lines 24 to reach the drive circuit 44  
24 and activation (e.g., opening, closing, partially  
25 opening or partially closing) of at least one  
26 downhole device 41 (or multiple downhole devices)  
27 based upon the downhole parameter or event.

28  
29 The foregoing description is directed to particular  
30 embodiments of the present invention for the purpose  
31 of illustration and explanation. It will be  
32 apparent, however, to one skilled in the art that

1 many modifications and changes to the embodiment set  
2 forth are possible without departing from the scope  
3 and the spirit of the invention. It is intended  
4 that the following claims be interpreted to embrace  
5 all such modifications and changes.



1     CLAIMS

2  
3     1.   A system for selective control of at least one  
4           downhole device among a plurality of downhole  
5           devices, comprising:

6           (a)   a surface control unit for transmitting a  
7                  command signal and an activation voltage  
8                  to a selected downhole device among a  
9                  plurality of downhole devices;

10          (b)   a downhole control module electrically  
11                  responsive to said surface control unit  
12                  for receiving, interpreting and  
13                  reformatting said command signal from said  
14                  surface control unit said control module  
15                  transmitting said reformatted command  
16                  signal and said activation voltage to at  
17                  least said selected downhole device; and,

18          (c)   an interface unit electrically coupled to  
19                  the selected downhole device for receiving  
20                  said reformatted command signal,  
21                  energizing the selected downhole device  
22                  and transmitting downhole data to said  
23                  downhole control module.

24  
25     2.   A system for selective control of at least one  
26           downhole device from among a plurality of  
27           downhole devices, said system comprising:

28           (a)   a surface power source for generating an  
29                  activation voltage for the at least one  
30                  downhole device; and,

31           (b)   a control unit for sensing at least one  
32                  downhole condition parameter; said control

1 unit electrically coupled to the one  
2 downhole device for activating the one  
3 downhole device responsive to a  
4 predetermined value of said downhole  
5 condition parameter.  
6

- 7 3. A method of controlling at least one downhole  
8 device, comprising:
- 9 (a) transmitting a command signal and  
10 activation voltage from a surface control  
11 unit;
  - 12 (b) receiving said command signal and said  
13 activation voltage by a downhole control  
14 module;
  - 15 (c) interpreting said command signal by said  
16 downhole control module;
  - 17 (d) reformatting said command signal by said  
18 downhole control module;
  - 19 (e) transmitting said reformatted command  
20 signal and said activation voltage to at  
21 least one predetermined downhole device  
22 among a plurality of downhole devices;
  - 23 (f) receiving said reformatted command signal  
24 at an interface unit electrically coupled  
25 to said predetermined downhole device;
  - 26 (g) actuating the predetermined downhole  
27 device in response to said reformatted  
28 command; and
  - 29 (h) transmitting downhole data from said  
30 interface unit to said downhole control  
31 module and to said surface control unit.



INVESTOR IN PEOPLE

Application No: GB 0201644.2  
Claims searched: 1 and 3

14

Examiner: Matthew Perkins  
Date of search: 27 May 2002

## Patents Act 1977 Search Report under Section 17

### Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): E1F FKF, FKG, FLM

Int Cl (Ed.7): E21B

Other: Online: WPI, EPODOC, PAJ

### Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	GB 2207161 A (OTIS) See pages 7 to 9	1 & 3

X Document indicating lack of novelty or inventive step  
Y Document indicating lack of inventive step if combined with one or more other documents of same category.  
& Member of the same patent family

A Document indicating technological background and/or state of the art.  
P Document published on or after the declared priority date but before the filing date of this invention.  
E Patent document published on or after, but with priority date earlier than, the filing date of this application.

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